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Updated Deep-Tow Acoustics/Geophysics System Compressional Velocity Database

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This memorandum report describes the Deep-Tow Acoustics/Geophysics System (DTAGS) compressional velocity database, a compilation of compressional velocity-layer thickness functions derived from DTAGS deep-tow multichannel seismic data. Geologic environments represented by the velocity functions included in this database include thick turbidite deposits, thick sediment basin deposits, sediment containing methane hydrate, and thin sediments overlying young basement. Horizontal sampling frequency (distance between velocity profiles) of the database ranges from 45 to 230 m. Vertical sampling frequency (layer thickness) ranges from 5 to 300 m.

These compressional velocity-layer thickness profiles were determined from DTAGS multichannel seismic data using standard semblance velocity analysis procedures. The ASCII files containing compressional velocity data are included on an MS-DOS 3-1/2" diskette, which may be ordered from the authors using the form included with this report. Included on the disk with the data files are two text files containing a description of the data file format and a list of the locations where the data were collected.

As DTAGS data continue to be collected and processed, this database will be updated to include all available compressional velocity functions.

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UPDATED DEEP-TOW ACOUSTICS/GEOPHYSICS SYSTEM COMPRESSIONAL VELOCITY DATABASE

Introduction

This report describes the high resolution Deep-Tow Acoustics/Geophysics System (DTAGS) compressional velocity database (which may be ordered on a diskette) and gives some guidelines for its use. The DTAGS compressional velocity database is a compilation of compressional velocity-layer thickness profiles derived from DTAGS multichannel seismic data. These data were collected between 1984 and 1993 on the Bermuda Rise, on the Blake Outer Ridge, near the Juan de Fuca Ridge, and in the Catalina Basin. The database consists of individual ASCII text files each containing compressional velocity as a function of layer thickness derived from a single seismic line. There may be more than one file containing profiles from different seismic lines from a single area. Each velocity-thickness profile gives the compressional velocity as a function of depth in terms of layer thickness, starting at the water-sediment interface, at a given location along the seismic line. Each set of profiles provides velocity as a function of range and depth along a single seismic line.

Horizontal sampling frequency of the velocity data ranges from 45 to 230 m, depending on the distance between gathers used in each velocity analysis. Vertical sampling frequency of the velocity data depends on the vertical spacing between the horizons used in the velocity analysis. Vertical resolution varies within a single data file due to lateral variability in the reflectivity along a single horizon and to rapid lateral changes in sediment structure. Velocity layer thicknesses range from 5 to 300 m. The maximum depth of penetration depends on the subbottom sediment type and thickness and ranges from ~120 m near the Juan de Fuca Ridge to ~650 m on the Blake Outer Ridge.

The velocity files are written in ASCII format on an MS-DOS 3-1/2" diskette which may be ordered from the authors using the order form included at the back of this technical note.

This is the first update in a planned series of reports documenting the seismoacoustic database predicated on DTAGS data. This report has been updated from the Naval Oceanographic and Atmospheric Research Laboratory Technical Note 257, "Deep-Tow Acoustics/Geophysics System Compressional Velocity Database." The previous Technical Note has been revised to include new data from the Juan de Fuca Ridge and the Catalina Basin.

Methods

The compressional velocity-layer thickness data were derived from multichannel seismic data collected using the Naval Research Laboratory's (NRL's) DTAGS system (Fig. 1). DTAGS is a deep-towed multichannel seismic system in which the source and hydrophone array are both towed 350 to 450 m above the seafloor at ocean depths up to 6000 m (Gettrust and Ross, 1990; Gettrust et al., 1991). The source is a Helmholtz transducer, which generates a chirp from 250 to 650 Hz with peak output of ~205 dB. The receiver array consists of 24 hydrophone groups 21 m apart with a maximum offset of 620 m. Data are digitized at 3125 samples/s and telemetered to the ship via the coaxial tow cable. The true depths of the source and array elements are given by depth transducers located on the source and array.

The high frequency source gives DTAGS data maximum vertical resolution of ~5 m. Lateral resolution of DTAGS data, as currently processed, is a function of the array length.

Horizontal resolution as high as ~100 m can be achieved by processing near trace shot gathers where laterally highly variable velocity or sediment structure need to be resolved. Common midpoint (CMP) gathers may be processed where sediment structure or compressional velocity vary significantly over less than 100 m laterally to give horizontal resolution on the order of 35 m.

The DTAGS data are processed using the following standard multichannel data processing procedures. Raw data are bandpass filtered from 250 to 650 Hz. The data are correlated with a calibrated reference trace to collapse the 250 - 650 Hz source chirp to a Ricker-type wavelet. Zero phase deconvolution is performed to reduce wavelet sidelobes.

Though, ideally, the array should remain perfectly horizontal as it is towed through the water, the array generally tilts up to 11° from horizontal. Static time shifts to compensate for this array tilt are determined from the difference between the source depth and the depth of the array, as given by the depth transducers. These static shifts are applied to the traces to compensate for deviation of the array from horizontal.

Next, stacking velocities, compressional velocities averaged over the paths travelled by the signal (Al-Chalabi, 1974), are determined from the multichannel data recorded at different source-receiver offsets. These stacking velocity estimates are made using semblance velocity analysis. Highest semblance is obtained for the best estimates of average velocity. At these velocities the horizons corrected for normal moveout (NMO) are flat across a gather. The data traces are then summed together (stacked) to check the accuracy of the stacking velocities. Where stacking velocity estimates are poor, horizons lose coherence in the stacked section. Stacking velocity profiles are refined at the locations where the velocity estimates looked poor and the section is re-stacked. If the best estimate stacking velocity profile still stacks the data incoherently, due to a high degree of lateral variability in sediment structure or velocity below the lateral resolution of the data, that stacking velocity profile is deleted.

After the best stacking velocities have been obtained, Dix's (1955) equation is used to convert the stacking velocity profiles to interval compressional velocity profiles. Interval velocity is the average compressional velocity of the sediment within a single layer. These interval velocity profiles are checked by converting the seismic data from time to depth. The appearance of structural features and discontinuities in the seismic depth section that are inconsistent with the sediment structure shown in the time section indicate the interval velocities at these locations are incorrect. These interval velocity profiles are deleted from the database.

Areas Covered

Several geologically distinct areas are represented by the compressional velocity data included in this database: thick turbidite sequences (Bermuda Rise), sediments containing methane hydrate (Blake Outer Ridge), thin sediment overlying young basalt basement (Juan de Fuca), and a thickly sedimented continental margin basin (Catalina Basin). Table 1 lists the specific areas, by latitude and longitude, covered by the database.

Bermuda Rise

File *bermuda1* contains a series of one-dimensional compressional velocity-layer thickness profiles as a function of range obtained from a ~3 km seismic line trending north-south on the Bermuda Rise in the North Atlantic Ocean (Table 1, Fig. 2). The seismic data (Fig. 3) resolve a ~450 m thick sequence of sediments consisting of middle Eocene to Oligocene turbidites

overlain by Miocene to Quaternary pelagic sediment (Tucholke et al., 1979; Gettrust et al., 1988; Bowles et al., 1991). An ~25 m thick layer of high impedance, coarse grained volcaniclastic turbidites extends from a range of 0.5 km to the right hand edge of the section (Fig. 3). The top and base of this layer were generally too rough to determine accurately compressional velocities for this layer.

TABLE 1
Locations of DTAGS Compressional Velocity Data

environment	file name	location	comments
thick turbidite	bermuda1	30°53'N,66°08'W- 30°55'N,66°07'W	Bermuda Rise
thick terrigenous sediment	blake1	30°41'N,75°32'W- 30°39'N,75°32'W	methane hydrate present (Blake Ridge)
thick terrigenous sediment	blake2	30°40'N,75°39'W- 30°39'N,75°35'W	little methane hydrate
thin sediment	juan4b	45°28'N,128°45'W- 45°24'N,128°45'W	parallel to Juan de Fuca Ridge, intersects *juan3b* at 4.8 km
thin sediment	juan3b	45°25'N,128°44'W- 45°25'N,128°47'W	intersects *juan4b* at 0.2 km
thick sediment basin	catln	33°10'N,118°31'W- 33°10'N,118°29'W	California continental borderland

Blake Outer Ridge

File *blake1* contains a series of velocity profiles obtained from an ~2.5 km seismic line trending north-south on the Blake Outer Ridge in the North Atlantic Ocean (Fig. 4, Table 1). The seismic data (Fig. 5a) resolve ~650 m of Miocene to Holocene hemipelagic silty clay (Hollister et al., 1972; Sheridan et al., 1983) deposited by contour currents (Markl and Bryan, 1983). A bottom simulating reflector (BSR) occurs at ~650 m depth in the sediment marking the base of a 400 m thick layer containing a high concentration of methane hydrate (Paull and Dillon, 1981; Rowe and Gettrust, 1993). The presence of methane hydrate within these sediments causes the compressional velocity of the sediment to be abnormally high, >2.1 km/s, for shallow marine sediments.

File *blake2* contains a series of velocity profiles from an ~7.9 km line running from west to east across the Blake Outer Ridge (Table 1, Fig. 4). These profiles are 5 km west of the data in file *blake1*, in the same geologic environment (Fig. 5b). These profiles extend to only ~425 m due to the lack of a BSR or other deeper horizons to enable velocity analysis to be performed. Absence of a BSR and generally lower compressional velocities indicate that little methane hydrate is present in these sediments (Rowe and Gettrust, 1993).

Juan de Fuca

File *juan4b* contains a series of compressional velocity profiles obtained from seismic data collected in the North Pacific Ocean along a 6.0 km line running parallel to the Juan de Fuca Ridge, ~95 km from the ridge (Fig. 6, Table 1). Sediment in this area is 100 to 150 m thick, overlying young basalt basement (Fig. 7). This thin sediment layer is made up of thinly bedded, flat lying turbidites overlying rough basalt basement (Carson, 1973). The compressional velocity profiles in this area are characterized by a low velocity zone in the upper 50 m of sediment (Rowe and Gettrust, 1991). No velocity estimates from the basalt were obtained due to the roughness of the basement. Where compressional velocity and sediment structure showed significant lateral variability over <100 m, e.g. over basement highs, CMP gathers were processed in order to increase the lateral resolution and accuracy of the compressional velocity-thickness profiles.

File *juan3b* contains velocity profiles obtained from a seismic line perpendicular to *juan4b* (Table 1) trending from east to west. The two profiles cross at 4.8 km on *juan4b* and 0.2 km on *juan3b*, as shown by the arrows in Figures 7 and 8. Sediment structure and compressional velocity derived from this orthogonal line is consistent with the sediment structure and velocity determined from in the north-south trending seismic line.

Catalina Basin

File *catln* contains compressional velocity profiles obtained from an ~1.5 km seismic line recorded in the Catalina Basin, lying between Santa Catalina Island and San Clemente Island off the coast of southern California (Table 1, Fig. 9). The seismic section (Fig. 10) shows ~100 to ~175 m of slightly deformed sediment layers overlying rough acoustic basement, the maximum depth of acoustic signal penetration. The sediment compressional velocity shows considerable variability across the section, consistent with the lateral variation in horizon reflectivity (Fig. 10). An ~20 m thick low velocity zone ~10 to ~25 m below the seafloor extends across the section. The upper ~175 m of sediments consist of late Pliocene to Quaternary age, mostly fine-grained hemipelagic sediment consisting of terrigenous silty clay interspersed with thin (<1 m) layers of sand and silt and biogenic silt and sand (Gorsline and Teng, 1989). The sediment layers within the basin have been deformed by earthquake-triggered gravity flows within the basin and by compressional tectonic stress (the Santa Catalina thrust fault runs east-west along the northern side of the basin) (Gorsline and Teng, 1989).

Database Format

The compressional velocity-thickness data are written as text files on a 3-1/2" high-density MS-DOS diskette. These text files may be read on any IBM-PC compatible system running MS-DOS using the "type" command or may be input into a computer program using the format given in Table 2. All velocity-thickness data files are displayed on the screen in the format shown in Table 2.

Each row on Table 2 represents a single formatted record. The first record in the text file gives the number of one-dimensional compressional velocity profiles included in the data file. The total number of profiles in a data file is different for each file and depends on the length of the seismic line from which the data were derived and the spacing between velocity semblance analyses. The sets of compressional velocity-thickness profiles follow this first record. The first record of each velocity-thickness profile, the profile header, gives the location of the profile along

the seismic line in meters and the number of thickness-velocity pairs within that profile (Table 2). Note that the first profile in each file will not necessarily be located at 0.0 m. The number of thickness-velocity pairs within each profile will vary from profile to profile within a single data file. Layer thickness is in meters, compressional velocity in meters per second. The top of the first layer is the water-sediment interface. No sea water compressional velocities or bathymetry data are included in this database.

TABLE 2
Compressional Velocity Data File Format

Fortran format	example (*bermuda1*)	parameter description
i3	34	*n*, the number of velocity profiles in this file
f8.2, i3	75.00 10	profile header 1: range in meters of profile 1 from the start of the line, and *i*, the number of thickness-velocity pairs in this profile
f8.2, f8.2	16.70 1581.66	thickness of layer 1, velocity in layer 1
		. . .
f8.2, f8.2	26.80 2589.79	thickness of layer *i*, velocity in layer *i*
. . .		. . .
f8.2, f8.2	3225.00 8	profile header *n*: range of profile *n* from the start of the line, and *k*, the number of thickness-velocity pairs in profile *n*
f8.2, f8.2	63.23 1579.74	thickness in layer 1, velocity in layer 1
		. . .
f8.2, f8.2	21.88 2144.96	thickness in layer *k*, velocity in layer *k*

Each file contains only 1 record giving the number of profiles in the file, this is the first record in the file. There is one profile header for each compressional velocity profile, the record preceding each set of thickness-compressional velocity pairs. In the example given in Table 2, from the file *bermuda1*, there are 34 profiles in the file, thus there are 34 sets of profile headers followed by thickness-velocity pairs. The first velocity profile is located 75.0 m from the start of the line shown in Figure 3 and contains 10 thickness-velocity pairs. The top layer in the

sediment is 16.70 m thick and has an average compressional velocity within the layer of 1581.66 m/s. The deepest sediment layer sampled at this location is 26.80 m thick with an average compressional velocity of 2589.79 m/s. The 34th velocity profile is located 3225.0 m from the beginning of the seismic line and contains 8 velocity-thickness pairs defining the compressional velocity-depth function. The uppermost sediment layer, immediately beneath the water-sediment interface, is 63.23 m thick and has an average compressional velocity of 1579.74 m/s. The deepest sediment layer is 21.88 m thick and has a compressional velocity of 2144.96 m/s.

Data formats given in column 1 of Table 2 use standard FORTRAN descriptors. Range of the profile along the seismic line and layer thickness are given in meters, compressional velocity is given in meters/second. Table 2, the data format description, is included on the diskette with the data files in the file *format*. Table 1, giving the locations where the data sets were collected, is also on the disk, in the file *directry*.

Guidelines for Modelling

Acoustic Models

Acoustic models require compressional velocity and density estimates as input. Signals are reflected where there is an abrupt change in sediment impedance, which is dependent on density and velocity. High resolution compressional velocity functions can be obtained directly from the DTAGS compressional velocity database for those areas covered (Table 1).

Though signal phase and partitioning of the reflected energy appear to be relatively insensitive to sediment density, results from DTAGS data analysis indicate that reflection strength is highly sensitive to changes in density. For this reason it is important that the density input to the acoustic model is accurate (Gettrust and Rowe, 1991). Estimates of in situ sediment density can be obtained from the Deep Sea Drilling Project reports from sites 386 and 387 (Tucholke et al., 1979) for the Bermuda Rise region and from sites 102, 103, 104 (Hollister et al., 1972), and 533 (Sheridan et al., 1983) for the Blake Outer Ridge region. Approximations of density as a function of depth for the other sites can be obtained from Hamilton's (1980) density functions, from the Nafe-Drake density curves (Ludwig et al., 1970), or from the Gardner et al. (1979) density function.

Elastic Models

Elastic models require estimates of shear velocity and anelastic attenuation as input, as well as compressional velocity and density. DTAGS data have been analyzed to obtain estimates of shear velocity within the upper ~50 m of seafloor sediment. Results show that shear velocity in these sediments is low, ~100 to ~300 m/s on the Bermuda Rise, with Poisson's ratio ~0.48 (Gettrust and Rowe, 1991). On the Blake Outer Ridge, shear velocities in the upper ~40 m of sediment are usually less than ~200 m/s with limited regions where shear velocity in thin layers reaches 500 to 600 m/s (Lindwall and Gettrust, pers. comm.).

Estimates of shear velocity as a function of depth for deeper (>50 m) sediments and for the Juan de Fuca Ridge and Catalina Basin sites can be obtained from Castagna et al. (1985) and Hamilton (1980). The low compressional velocities of the Juan de Fuca Ridge sediments and the high Poisson's ratio observed in the sediments in the other regions suggests shear velocity within these sediments will also be on the order of 100 to 300 m/s. More detailed shear velocity estimates will be available as more DTAGS data are processed.

Estimates of anelastic attenuation should be constrained by the known sediment compressional velocity, density, and shear velocity and by the sediment type in a given area. Empirical estimates of attenuation as a function of depth may be obtained from Hamilton (1980) for a variety of sediment types and geologic environments. Wrolstad (1980) gives experimentally derived attenuation values for marine sediments near the Juan de Fuca Ridge. Our limited modelling efforts indicate that model results are not sensitive to attenuation.

Summary

The DTAGS compressional velocity database contains compressional velocities as a function of geographic region, range, and depth (in terms of layer thickness) within the sediment. These compressional velocity profiles were derived from DTAGS multichannel seismic data using standard multichannel seismic processing techniques. Several geologically distinct regions are represented in the database: thick terrigenous turbidites, thick fine grained sediment containing methane hydrate, thin sediment over young oceanic crust, and thick continental margin basin sediments. The data files are written in ASCII text format on a 3-1/2" high-density MS-DOS diskette. The compressional velocities from this database may be used directly as input to acoustic models, providing reasonable estimates of density are also made. Elastic models require shear wave velocity and attenuation input as well as compressional velocity and density in order to accurately model the elastic subbottom response. Estimates of shear velocity in the Bermuda Rise sediments have been made from DTAGS data (Gettrust and Rowe, 1991). The database will be expanded to include shear velocities and compressional velocities from more sites as more DTAGS data are processed.

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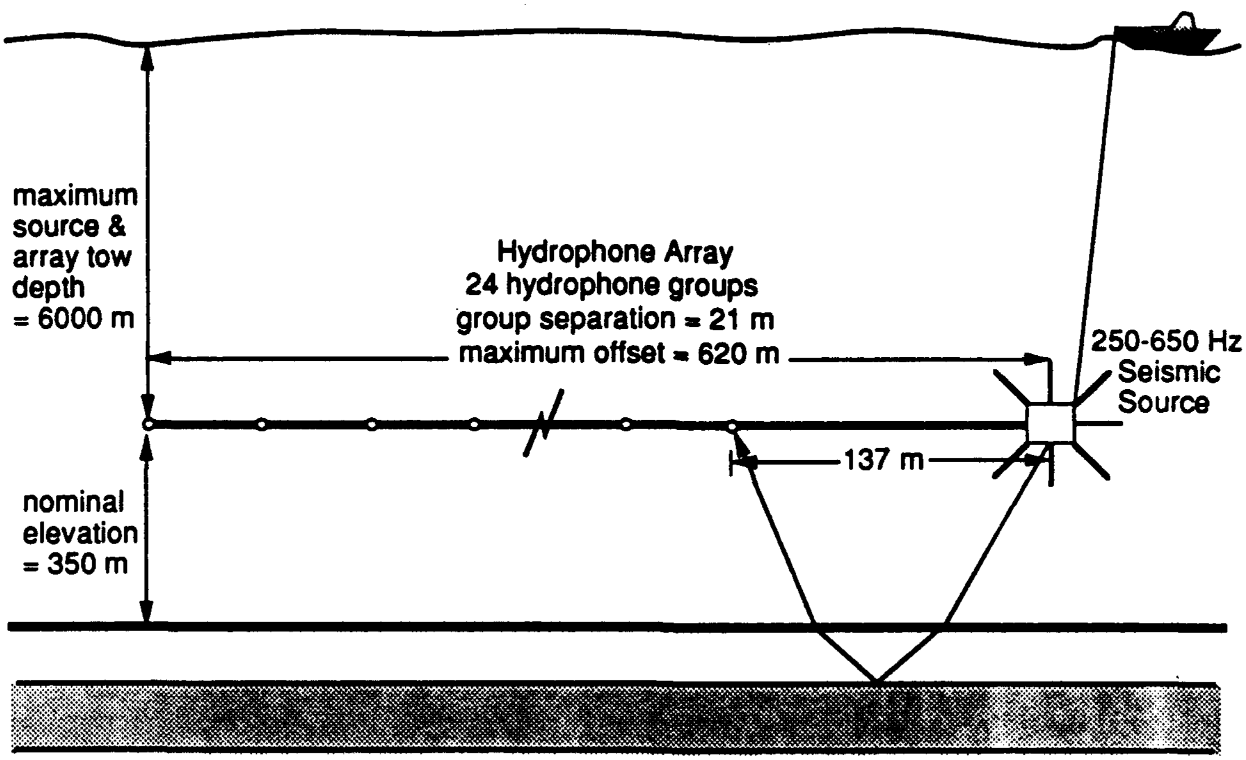

Figure 1. DTAGS instrument configuration showing the source and array geometry and proximity to the bottom when deployed.

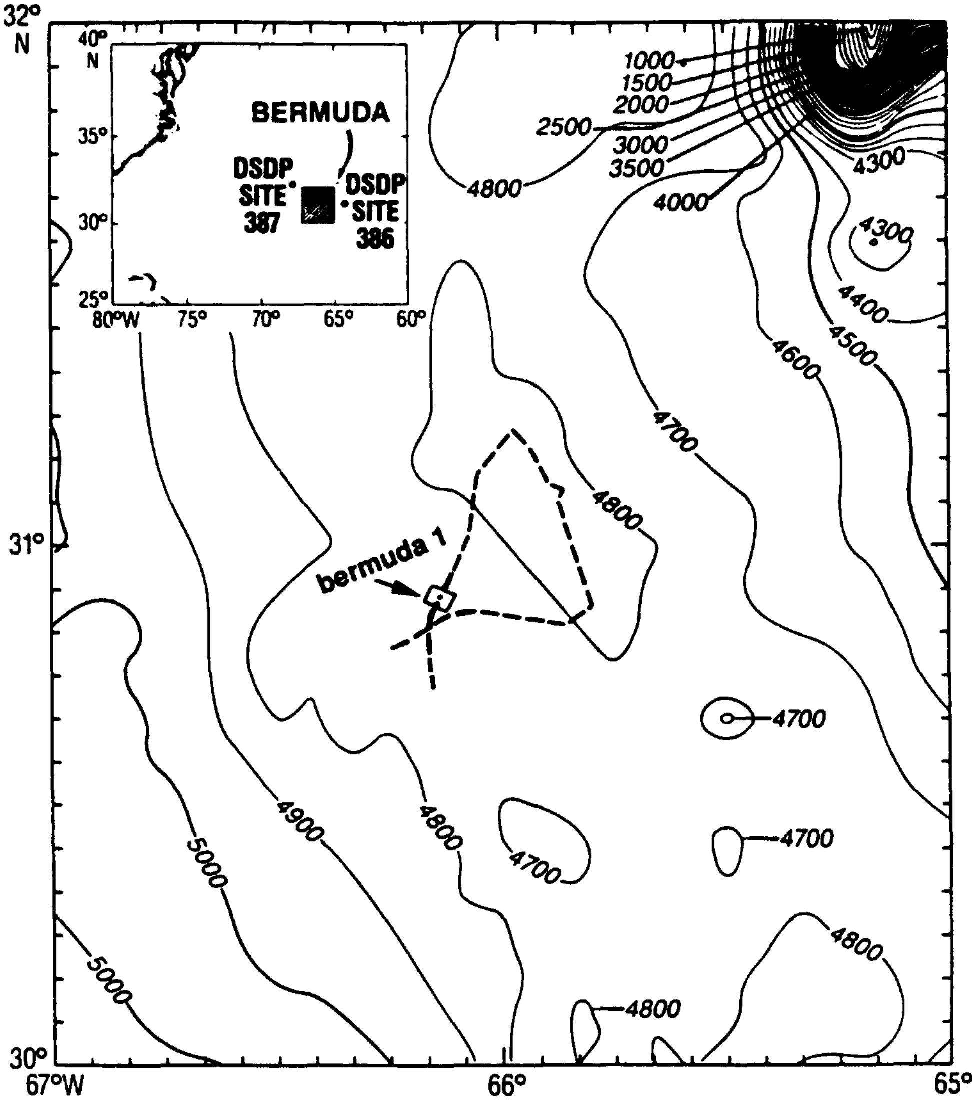

Figure 2. Map showing the location of the velocity profiles in file *bermuda1* (track within the boxed region). The dashed line is the entire ship track during the experiment. (Contours are water depth in meters.)

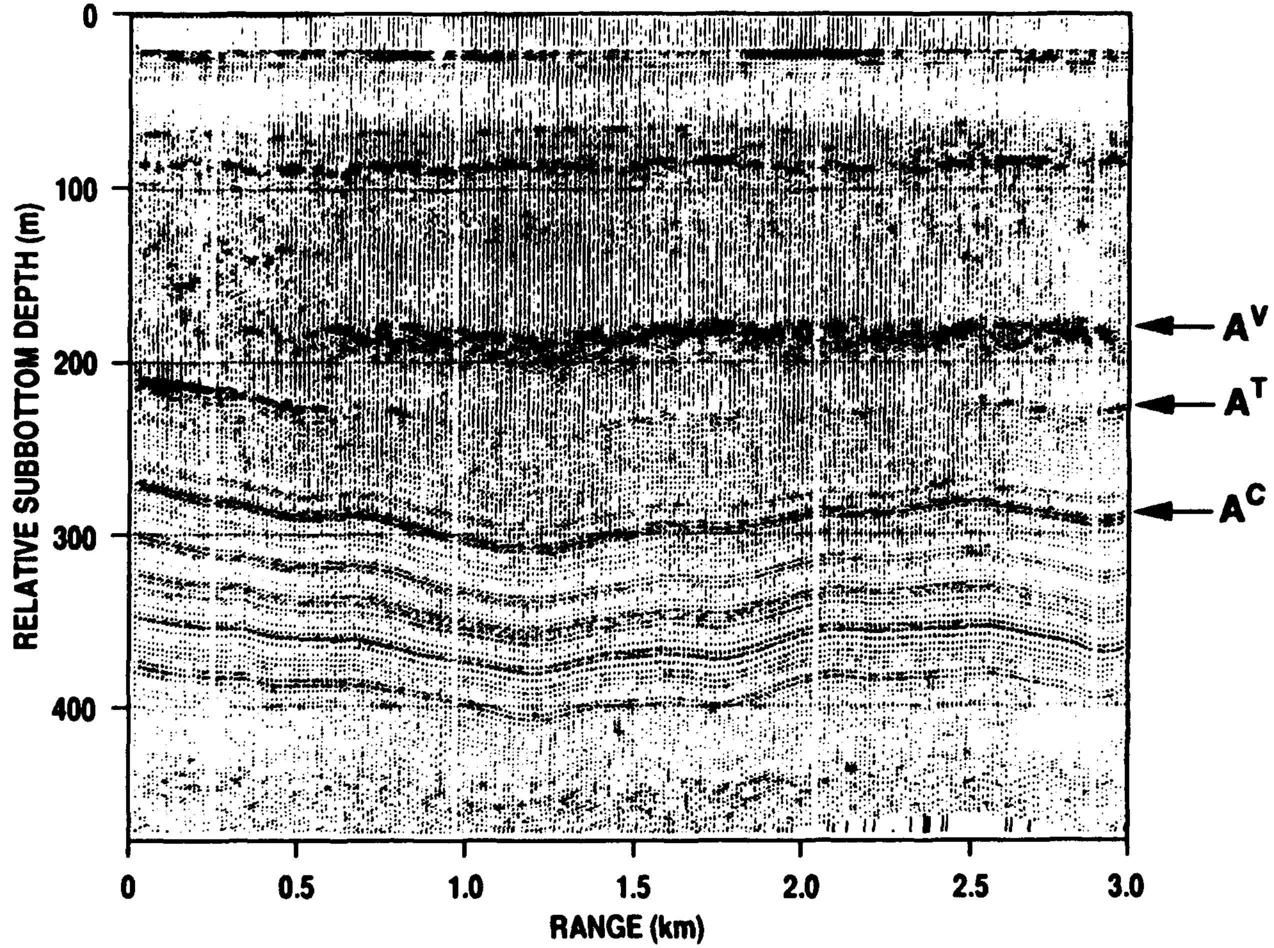

Figure 3. Twenty-four-fold stacked multichannel seismic section of the data from the Bermuda Rise used to obtain the compressional velocity estimates in *bermuda1*. A^T, A^V, and A^C, are turbidite layers identified by Tucholke and Mountain (1979).

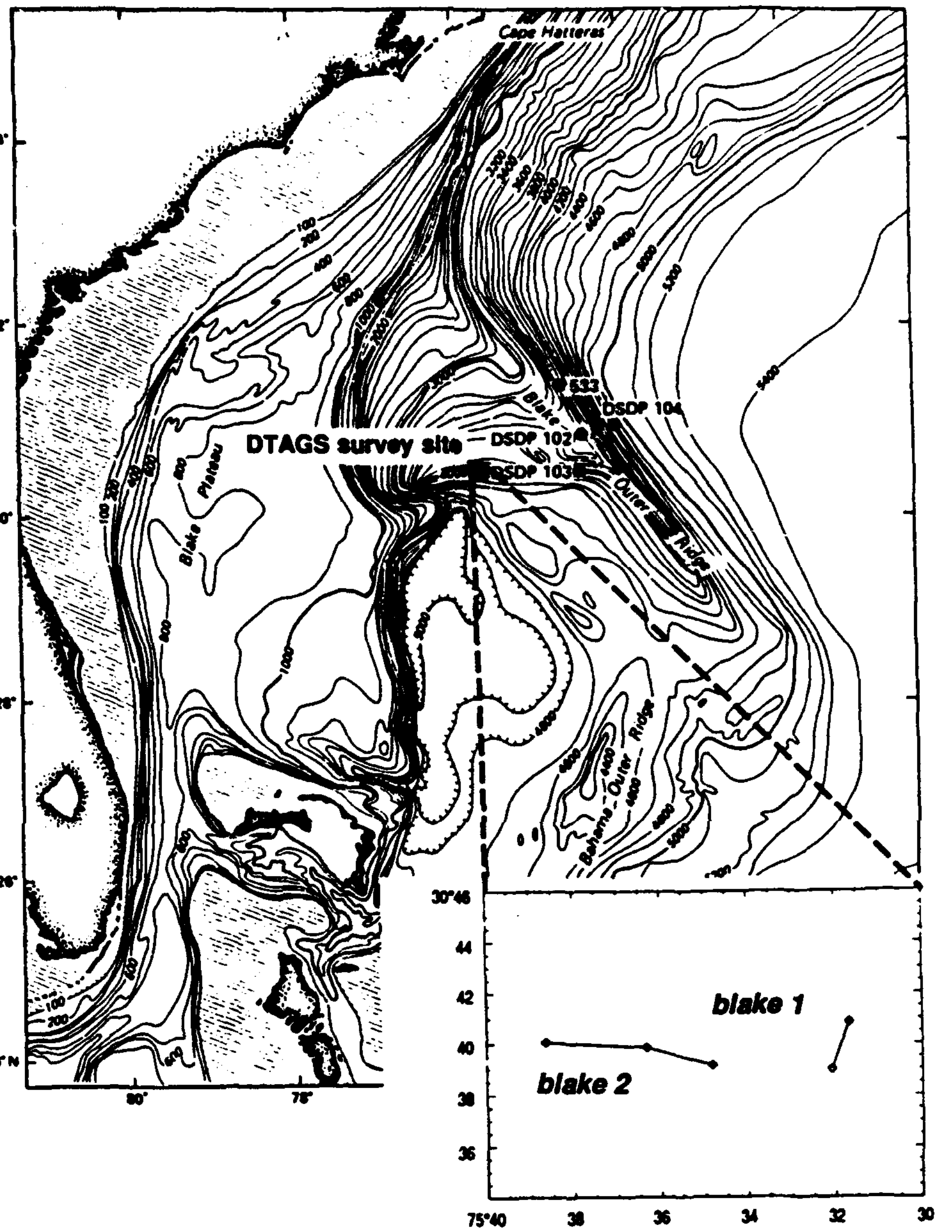

Figure 4. Map showing the location of the velocity profiles in files *blake1* and *blake2*. (Contours are water depth in meters.)

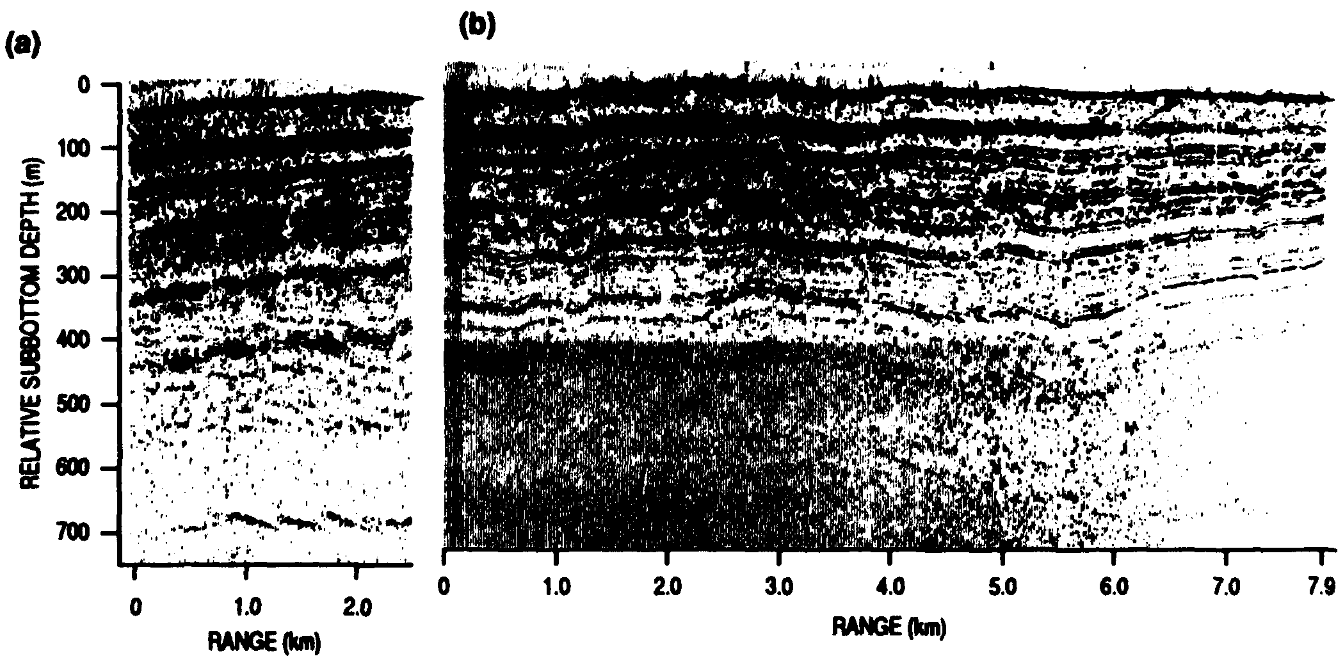

Figure 5. (a) Single channel, near trace seismic section from the data used to obtain the velocity estimates in *blake1*. The BSR occurs at ~700 m depth.
(b) Single channel, near trace seismic section from the data used to obtain the velocity estimates in *blake2*.

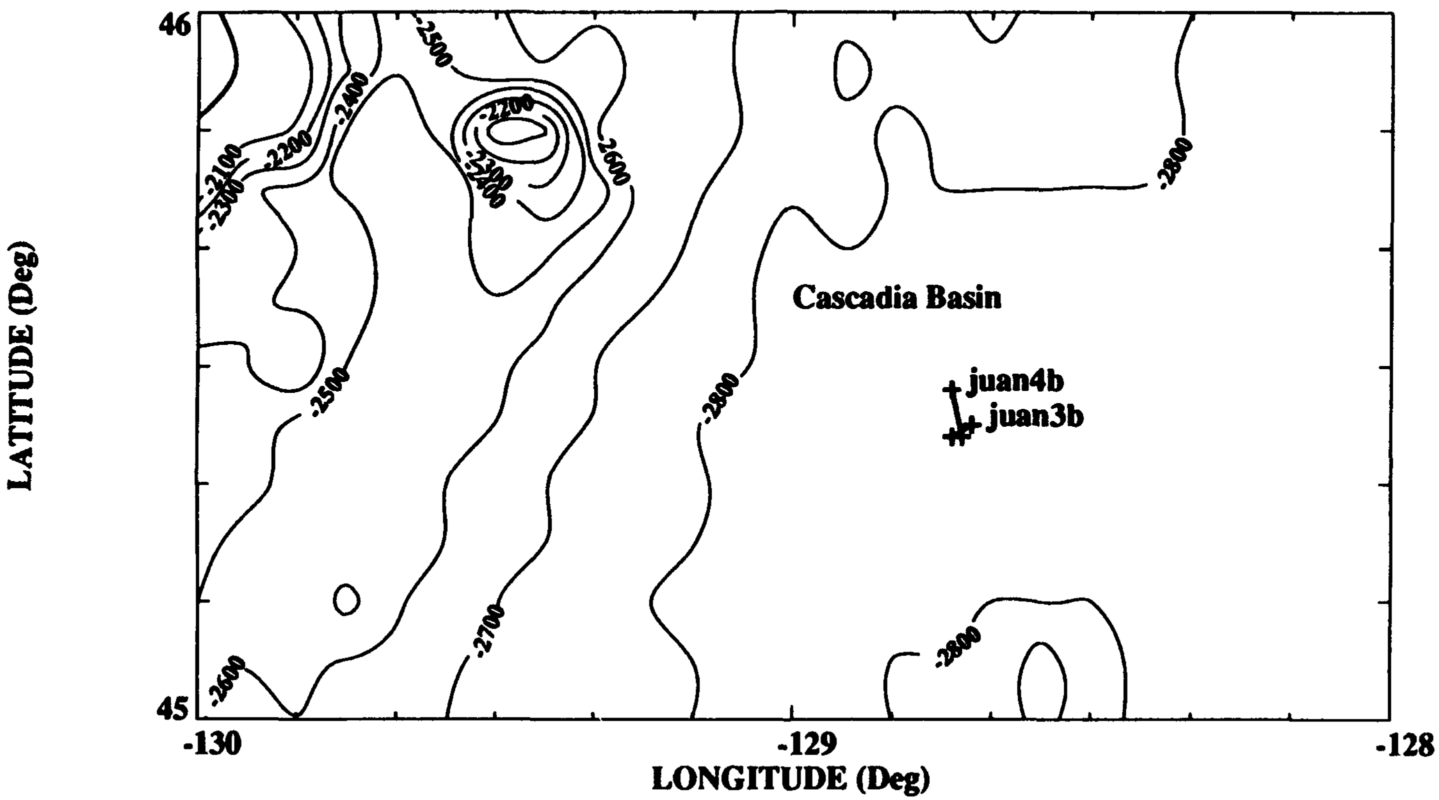

Figure 6. Map showing the location of the velocity profiles in files *juan3b* and *juan4b*. (Contours are water depth in meters.)

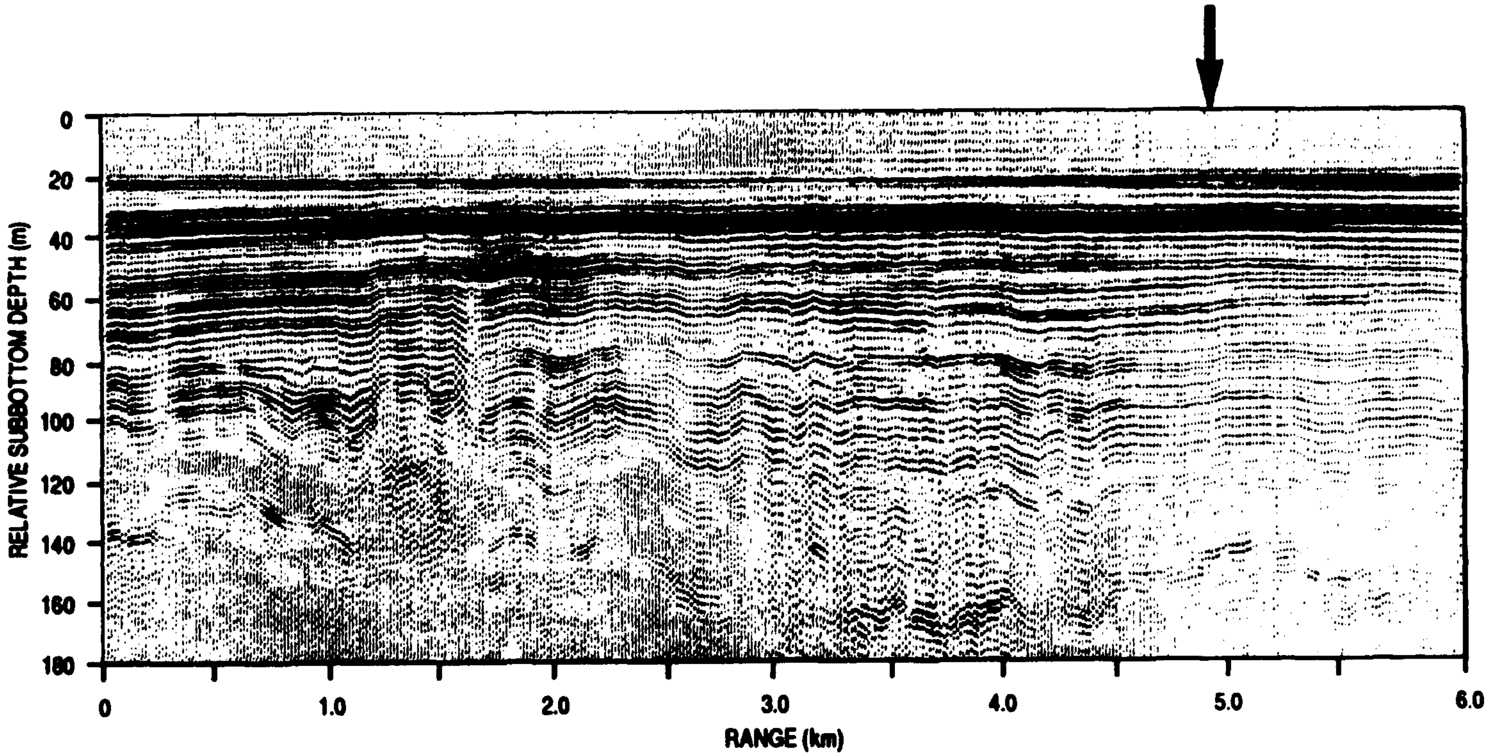

Figure 7. Stacked multichannel seismic section of the data used to obtain velocity estimates in *juan4b* showing thinly bedded turbidite layers overlying rough basaltic basement. Arrow shows where this line crosses line *juan3b*, shown in Figure 8.

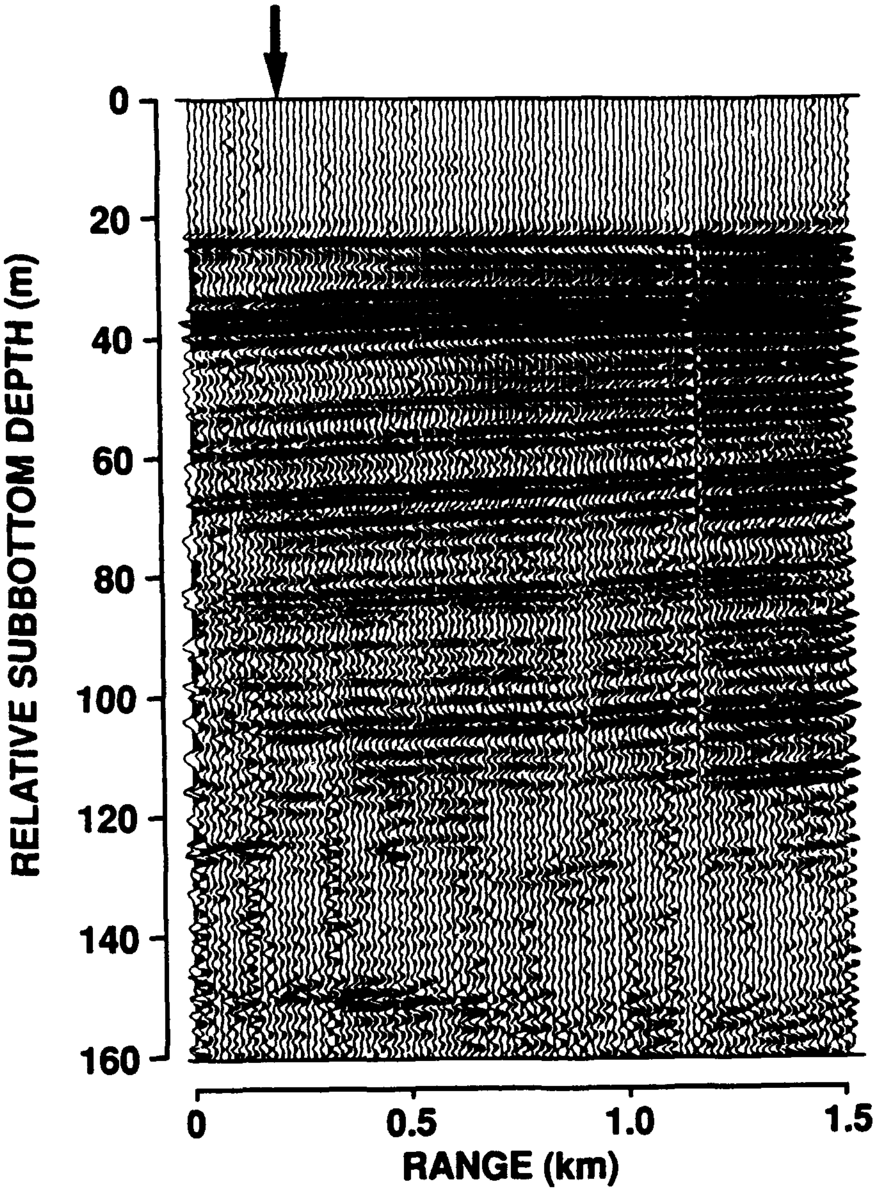

Figure 8. Twenty-four-fold stacked multichannel seismic section from data used to obtain velocity estimates in file *juan3b*. Arrow indicates where this line crosses the line shown in Figure 7.

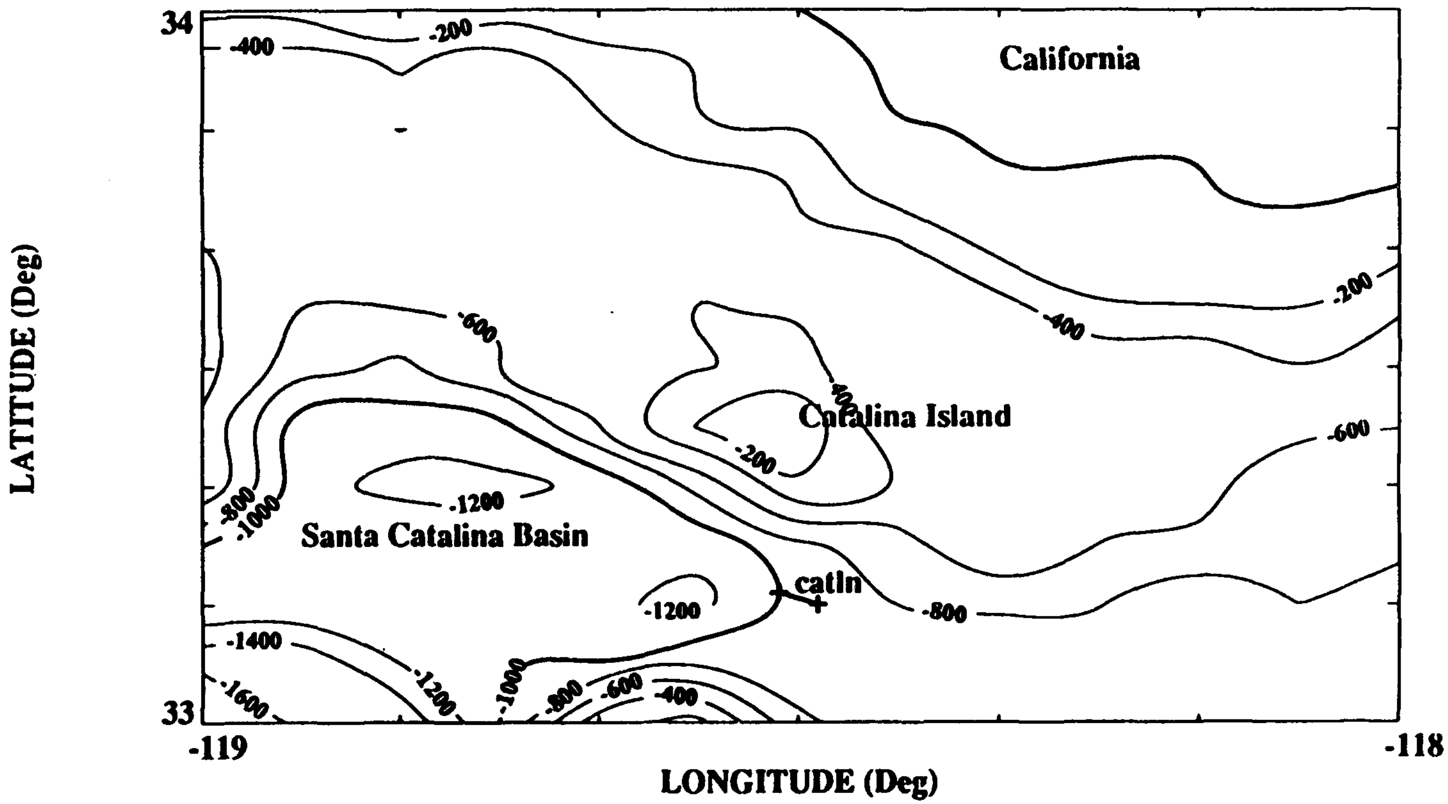

Figure 9. Map showing the location of the velocity profiles in file *catln*. (Contours are water depth in meters.)

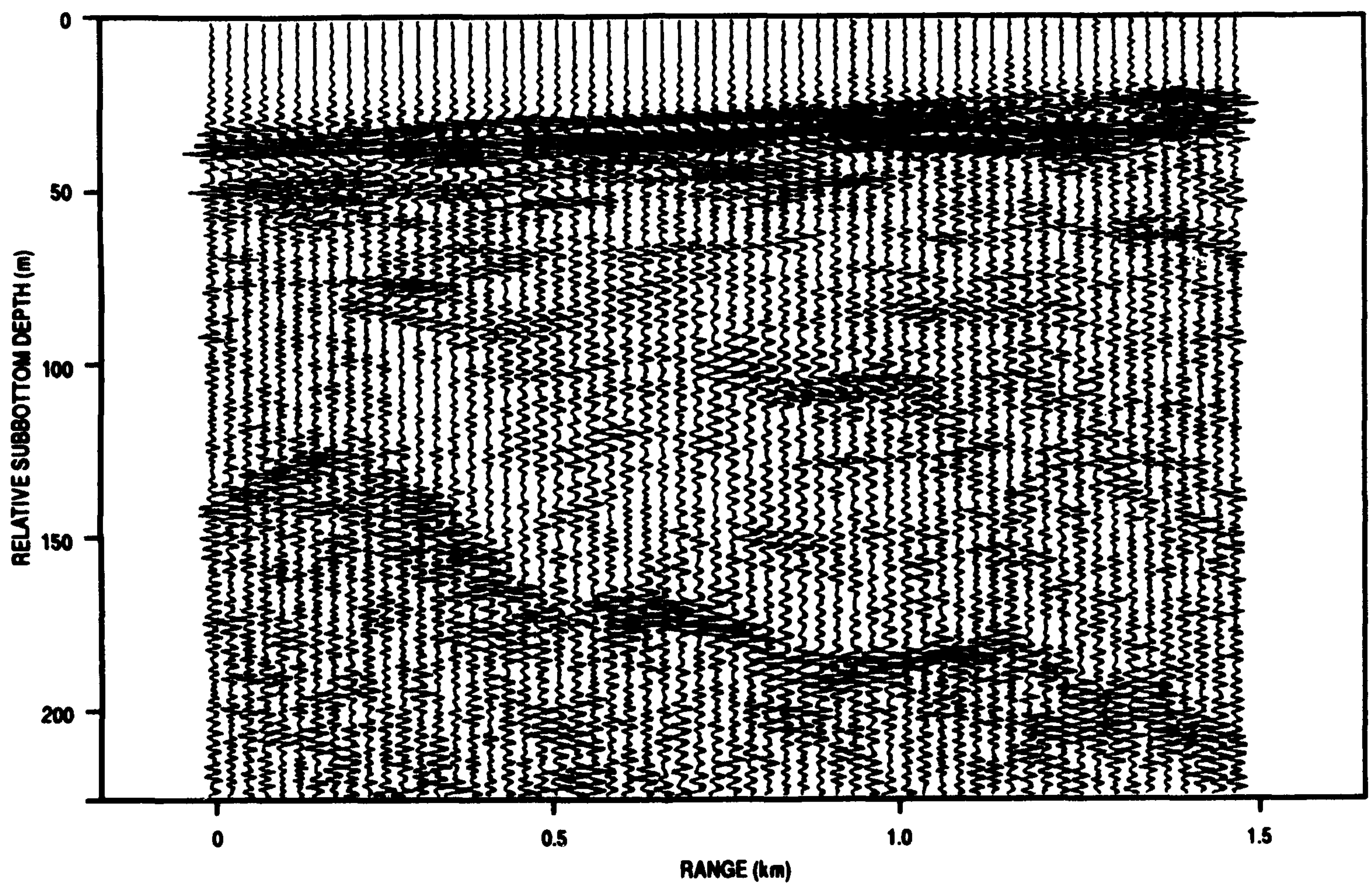

Figure 10. Stacked multichannel seismic section of the data used to obtain the velocity estimates in *catln* showing the laterally variable reflectivity of the slightly deformed sediment layers. Acoustic basement is the rough horizon ~100 to ~175 m below the sea floor.

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